Effects of Replacement Finisher Feed and Length of Feed Withdrawal on Broiler Carcass Yield and Bacteria Recovery

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ABSTRACT A study was conducted to determine the effects of a replacement finisher feed (RF) on carcass yield and carcass bacteria recovery. RF is a commercial formulation of a D-glucose polymer (maltodextrin) with added salts and vitamins. Commercial male broilers (41 d of age) were given either RF or control-feed (traditional starter feed) for 8 h, followed by feed withdrawal for 0, 4, 8, or 12 h before processing. During processing, whole carcass rinses (WCR) of pre-eviscerated (feathers, feet, and heads removed) and eviscerated carcasses were analyzed for recovery of bacteria. Body weight at initiation of feed withdrawal (catch weight) or at slaughter (dock weight) did not differ significantly due to type of feed. Live shrink, as a percentage of live weight, increased significantly with time off feed. Birds fed RF exhibited significantly lower live shrink than the birds fed the control feed at 8 and 12 h after feed withdrawal. This difference between types of feed, RF or control, was approximately 0.1% per hour of feed withdrawal. Type of feed or length of feed withdrawal did not affect *Campylobacter*, coliform, or *Escherichia coli* counts recovered from WCR of pre-eviscerated or eviscerated carcasses. These data demonstrate that feeding RF to broilers for 8 h before initiation of feed withdrawal may reduce live shrink without affecting carcass *Campylobacter*, coliforms, or *E. coli* recovered.

(*Key words*: broilers, carcass bacteria, carcass yield, feed withdrawal, live shrink)

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INTRODUCTION

In 1994, the USDA published a proposed rule on enhanced poultry inspection that initiated a zero tolerance policy for visible fecal contamination of poultry carcasses (USDA, 1998). Two years later, the USDA mandated the Pathogen Reduction, Hazard Analysis and Critical Control Point (HACCP) System regulation, which enforced the zero tolerance fecal policy that was stated in the previous proposal (USDA, 1996; USDA, 1998). According to the zero tolerance policy, establishments that slaughter poultry must remove all visible feces from a carcass before the carcass may advance to the chilling stage (USDA, 1996; USDA, 1998). If visible fecal contamination cannot be removed, the carcass is considered to be adulterated and must be condemned (USDA, 2003). Washing, trimming, or vacuuming the carcasses either on or off the processing line may be used to remove fecal contamination, but these procedures may be expensive, time consuming, and often may cause additional logistical problems for the establishments (Thornton, 1994).

Previous reports have implied that the frequency of carcass contamination is not only dependent upon the amount and condition of the feces in the broiler's gastrointestinal tract during processing but also on the integrity of the intestines and the efficiency of the processing equipment and plant employees (Bilgili, 1988; Northcutt and Savage, 1996). Consequently, it is a common practice for feed and water to be removed from broilers during the last few hours before processing to allow time for the birds to void their gastrointestinal tracts. Research has shown that incidence of carcass contamination and weight loss from feed deprivation (live shrink) are minimal for broilers held without feed for 8 to 12 h (Smidt et al., 1964; Wabeck, 1972; Veerkamp, 1986; Lyon et al., 1991; Northcutt and Buhr, 1997; Buhr et al., 1998). Live shrink has been found to range from 0.18 to 0.43% of the broiler's BW per hour of feed withdrawal. Variation in broiler live shrink depends not only upon gender, age, and bird health, but also on bird housing and holding conditions (Wabeck, 1972; Fletcher and Rahn, 1982; Veerkamp, 1986; Lyon et al., 1991; Buhr et al., 1998). It has been reported

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Abbreviation Key: CF = control feed; FW = feed withdrawal; NY = New York; NYD1 = New York dressed weight as a percentage of catch weight; NYD2 = New York dressed weight as a percentage of dock weight; RF = replacement finisher feed; SH = shell yield; WCR = whole carcass rinse.

that the majority of the weight lost by broilers during the first 5 to 6 h of feed withdrawal may be attributed solely to evacuation of the gastrointestinal tract (Benoff, 1982; Northcutt and Buhr, 1997). After this period, live shrink translates into loss of eviscerated carcass yield (Benoff, 1982; Northcutt and Buhr, 1997).

Because of increased emphasis on minimizing carcass contamination and the difficulty in balancing contamination rate with live shrink, several attempts have been made to develop alternative broiler feeds that reduce the intestinal contents at slaughter without compromising yield. Many of these attempts have focused solely on minimizing visible fecal contamination, with little attention to the actual microbiological counts. The present study was conducted to evaluate the effects of a replacement finisher feed in combination with various feed withdrawal times on broiler carcass yield and microbiological characteristics.

MATERIALS AND METHODS

Broilers

Campylobacter-positive flocks were identified on two separate occasions by analyses of cecal droppings using sterile swabs in commercial houses containing 28-d-old broilers. On each occasion, six swabs were used per house. One house was evaluated on each of six different farms. During sampling, one swab was placed into six separate cecal droppings. After sampling, swabs were placed into sterile tubes, and the tubes were capped. Capped tubes were put into beakers on ice and transported to the laboratory for *Campylobacter* analysis. Birds were obtained only from houses containing *Campylobacter*-positive droppings.

On two separate occasions, 352, 30-d-old commercial male broilers were caught, transported to the university research facility and placed into floor pens on clean pine shavings. Twenty-two birds were placed into each of 16 pens. Birds were given ad libitum access to traditional grower feed (3,200 kcal ME/kg, 19% CP) until 41 d of age at which time half of the birds (8 pens of broilers) were given a replacement finisher feed (RF). Feed was also replaced for control broilers with control feed (CF), which was traditional starter feed (3,100 kcal ME/kg, 23% CP) because it approximated the particle size of RF. All feed replacements were for 8 h.

Table 1 shows a summary of the type of feed (CF or RF) along with the length of feed withdrawal. The RF used in the present study was a commercial formulation[2] of a D-glucose polymer (Maltodextrin) with added salts and vitamins. Composition of RF was evaluated by Farhat et al. (2002).

TABLE 1. Treatment variables for type of feed and length of feed withdrawal combinations

Treatment	Type of feed	Length of feed withdrawal (h)
CF0	Control	0
CF4	Control	4
CF8	Control	8
CF12	Control	12
RF0	Replacement	0
RF4	Replacement	4
RF8	Replacement	8
RF12	Replacement	12

At the end of 8 h of feeding with CF or RF, birds were weighed (catch weight), and feed was removed for 0, 4, 8, or 12 h before processing (2 pens per feed type and feed withdrawal period). Birds were allowed access to water during the first hour of the feed withdrawal period. After 1 h on water but not feed, birds were caught, cooped, and held on concrete flooring in the grow-out house to minimize litter consumption. Immediately before processing, cooped broilers were transported less than 0.2 km to the pilot plant facility, where birds were unloaded and weighed.

Processing

All birds were electrically stunned (two-stage electrical stunner[3]: 14 V, pulsed DC at approximately 550 Hz for 18 s, followed by 14 V, 60 Hz for 9 s), killed by hand using a conventional unilateral neck cut to sever the carotid artery and jugular vein, and bled for 120 s. Carcasses were scalded for 2 min at 52°C in an air-agitated commercial scalder[4], and mechanically defeathered for 30 s in a single unit, in-line commercial picker.[5]

After removing the head and hocks, carcasses were weighed [New York (NY) dressed weight] and an opening cut was made for mechanical evisceration using an in-line eviscerator[6]. Following evisceration, the neck was removed and carcasses were washed (final wash) and weighed (shell weight). Variables, descriptions of carcass weights and formulas for yield calculations are shown in Table 2.

Microbiological Analyses

Four carcasses per treatment and replication were subjected to a whole carcass rinse (WCR) before (NY dressed) and after (shell) evisceration. Each carcass was placed into a clean plastic bag with 100 mL of sterile PBS and shaken vigorously by hand in a 1-foot arc for 60 s. Each carcass was aseptically removed from the bag, allowed to drain briefly into the bag, and then discarded. Serial dilutions of the rinse were made in PBS, and *Campylobacter* was enumerated by plating in duplicate onto the surface

[2]Grain Processing Corporation, Muscatine, IA.
[3]Simmons model SF-7001, Simmons Engineering Co., Dallas, GA.
[4]Cantrell Scalder Model SS300CF, Cantrell Machine Co., Inc, Gainesville, GA.
[5]Cantrell Picker Model CPF-60, Cantrell Machine Co., Inc., Gainesville, GA
[6]Cantrell Eviscerator Model Mark 4, Cantrell Machine Co., Inc., Gainesville, GA

TABLE 2. Variables and descriptions for weights and yield calculations

Variable	Description
Catch weight (kg)	Individual bird weight at the time feed is withdrawn
Dock weight (kg)	Individual bird weight immediately prior to slaughter
New York dressed weight (kg)	Individual carcass weight after bleeding, picking and removal of head and feet
Shell weight (kg)	Individual prechill eviscerated carcass weight without giblets or neck
Live shrink weight (kg)	Individual weight loss due to time without feed (catch weight – dock weight)
Live shrink (%)	(Live shrink weight/catch weight) × 100
NYD1 (%)	(New York dressed weight/catch weight) × 100
NYD2 (%)	(New York dressed weight/dock weight) × 100
SH1 (%)	(Shell weight/catch weight) × 100
SH2 (%)	(Shell weight/dock weight) × 100
SH3 (%)	(Shell weight/New York dressed weight) × 100

TABLE 3. Means and standard deviations for catch weight, dock weight, and live shrink between types of feed and times off feed (treatment[1])

Treatment	Catch weight (kg)	Dock weight (kg)	Live shrink (%)
CF0	2.53 ± 0.34	2.52 ± 0.35	0.4 ± 0.7[e]
RF0	2.54 ± 0.33	2.53 ± 0.34	0.5 ± 1.8[e]
CF4	2.64 ± 0.33	2.57 ± 0.32	2.4 ± 1.2[d]
RF4	2.61 ± 0.23	2.56 ± 0.23	1.9 ± 1.2[d]
CF8	2.65 ± 0.29	2.55 ± 0.28	3.8 ± 1.7[b]
RF8	2.61 ± 0.26	2.54 ± 0.25	3.0 ± 2.2[c]
CF12	2.64 ± 0.30	2.52 ± 0.29	4.6 ± 2.8[a]
RF12	2.60 ± 0.29	2.51 ± 0.28	3.4 ± 1.4[bc]
P	0.7282	0.9837	0.0001

[a–e]Means in the same column without common superscripts are significantly different.

[1]Type of feed and times off feed treatments are described in Table 1; n per mean = 80.

of Campy-cefex agar (Stern et al., 1992). A 0.1-mL sample was spread on the surface of each plate with a sterile loop, and plates were incubated at 42°C for 48 h in a microaerophilic environment (5% O_2, 10% CO_2, and 85% N_2). Colony-forming units characteristic of *Campylobacter* were counted. Each colony type identified as *Campylobacter* was confirmed for genus by examination of cellular morphology and motility on a wet mount under phase-contrast microscopy.

Total aerobic bacterial populations were enumerated on plate count agar.[7] A 0.1-mL sample from a serial dilution of the rinse diluent was plated in duplicate on the surface of the agar, spread, and incubated at 37°C for 18 to 24 h prior to counting the resulting colony-forming units. Coliform and *E. coli* counts were made by plating 1 mL from a serial dilution of the rinse diluent onto duplicate *E. coli* petrifilm plates.[8] Plates were incubated at 37°C for 18 to 24 h, and colony types characteristic of coliforms and *E. coli* were counted.

Statistical Analyses

Data were analyzed using the ANOVA option of the general linear model procedure of SAS software (SAS Institute, 1999). The model tested the main effects of type of feed (RF or CF), time off feed (0, 4, 8, and 12 h), and replication as well as first level interactions using residual error. Due to consistent feed and withdrawal time interactions, data were analyzed by treatment (type of feed and feed withdrawal times). When there were significant treatment-by-replication interactions, that mean square error was used to test significance of treatment. Means were separated using the Duncan's multiple range test option using the appropriate test error as previously described.

RESULTS AND DISCUSSION

The effect of broiler treatment or the combination of the type of feed (CF or RF) and length of feed withdrawal (0 to 12 h) on broiler catch weight, dock weight, and live shrink are shown in Table 3. BW at the initiation of feed withdrawal (catch weight) ranged from 2.53 to 2.65 kg and was not different ($P > 0.05$) among treatments. Additionally, BW at slaughter (dock weights) were comparable for all treatments, ranging from 2.51 to 2.57 kg. Live shrink for broilers given either type of feed (CF or RF) increased for those birds on longer feed withdrawal schedules (0.4 to 4.6% for CF0 to CF12; 0.5 to 3.4% for RF0 to RF12). Irrespective of type of feed, there was no difference in live shrink for full fed broilers (0.4% for CF0; 0.5% for RF0) and no difference in live shrink for birds held without feed for 4 h (2.4% for CF4; 1.9% for RF4). Birds held without feed for 8 and 12 h lost 0.8 and 1.2% more BW when fed CF versus RF. On a per hour basis, live shrink was 0.47% for CF8 (approximately 12 g/h) versus 0.38% for RF8 (approximately 10 g/h) and 0.38% for CF12 (approximately 10 g/h) versus 0.28% for RF12 (approxi-

[7]Becton Dickinson. Sparks, MD.

[8]3 M Health Care. St. Paul, MN.

TABLE 4. Means and standard deviations for New York dressed weight, New York dressed yield 1, and New York dressed yield 2 among types of feed and times off feed (treatment[1])

Treatment	NY dressed weight (kg)	NYD1 (%)[2]	NYD2 (%)[2]
CF0	2.17 ± 0.32	85.3 ± 2.0[a]	85.6 ± 2.0[bc]
RF0	2.17 ± 0.30	85.1 ± 2.1[ab]	85.6 ± 1.5[bc]
CF4	2.21 ± 0.28	84.0 ± 1.5[abc]	86.1 ± 1.2[ab]
RF4	2.19 ± 0.21	83.9 ± 1.3[bc]	85.1 ± 1.0[bc]
CF8	2.19 ± 0.22	82.2 ± 1.8[d]	85.3 ± 1.4[c]
RF8	2.18 ± 0.23	83.3 ± 1.5[cd]	85.8 ± 1.6[abc]
CF12	2.18 ± 0.26	82.3 ± 1.8[d]	86.4 ± 3.2[a]
RF12	2.15 ± 0.24	83.0 ± 1.4[cd]	85.9 ± 1.4[abc]
P	0.7163	0.0039	0.0178

[a–c]Means in the same column without common superscripts are significantly different.

[1]Type of feed and times off feed treatments are described in Table 1; n per mean = 80.

[2]NYD1 = (New York dressed weight/catch weight) × 100; NYD2 = (New York dressed weight/dock weight) × 100.

TABLE 5. Means and standard deviations for shell weight, shell yield 1, shell yield 2, and shell yield 3 among types of feed and times off feed (treatment[1])

Treatment	Shell weight (kg)	SH1 (%)	SH2 (%)	SH3 (%)
CF0	1.77 ± 0.25	70.0 ± 2.1	70.3 ± 2.2[d]	82.2 ± 2.7
RF0	1.79 ± 0.25	70.3 ± 2.4	70.6 ± 2.0[cd]	82.6 ± 1.9
CF4	1.84 ± 0.25	69.6 ± 2.0	71.3 ± 1.8[bc]	82.8 ± 1.9
RF4	1.83 ± 0.19	70.0 ± 2.3	71.4 ± 2.3[b]	83.6 ± 2.6
CF8	1.84 ± 0.22	69.2 ± 2.7	71.9 ± 2.4[ab]	84.5 ± 3.0
RF8	1.84 ± 0.20	70.2 ± 2.1	72.4 ± 2.0[a]	84.3 ± 1.9
CF12	1.83 ± 0.22	69.2 ± 2.1	72.6 ± 3.1[a]	84.1 ± 1.8
RF12	1.82 ± 0.21	70.2 ± 2.3	72.6 ± 2.1[a]	84.5 ± 2.5
P	0.8427	0.2730	0.0001	0.1661

[a–d]Means in the same column without common superscripts are significantly different.

[1]Type of feed and times off feed treatments are described in Table 1; n per mean = 80.

[2]SH1 = (shell weight/catch weight) × 100; SH2 = (shell weight/dock weight) × 100; SH3 = (shell weight/New York dressed weight) × 100.

mately 7 g/h). Although a difference of 2 to 3 g/h weight loss may not appear to be great, it would equate to 40 kg/h live weight for a house of 20,000 broilers. The results for live shrink of broilers on CF agree with data previously reported for broilers held without feed for 12 h (Fletcher and Rahn, 1982; Benibo and Farr, 1985; Veerkamp, 1986; Lyon et al., 1991; Buhr et al., 1998). Additionally, live shrink for broilers in the RF12 treatment group (3.4%) was comparable to the live shrink for broilers in the CF8 (3.8%) and RF8 (3.0%) treatment groups.

The NY dressed weight did not differ ($P > 0.05$) due to treatment, ranging from 2.17 to 2.21 kg (Table 4). This trend continued when the NY dressed weight was expressed either as a percentage of the catch weight (NYD1) or as a percentage of the dock weight (NYD2). For NYD1, there was a significant decrease in yield for broilers in the CF12 treatment group as compared to broilers in the CF0 treatment group (decrease of 3%). The change in NYD1 for broilers fed RF0 (85.1%) and RF12 (83%) occurred more gradually. All of the carcasses within the RF

TABLE 6. Recovery of *Campylobacter*, coliforms, and *Escherichia coli* from New York dressed and eviscerated carcasses (shell)[1] among types of feed and times off feed (treatment[2])

	NY Dressed[3]			Shell[3]		
Treatment	*Campylobacter*	Coliforms	*E. coli*	*Campylobacter*	Coliforms	*E. coli*
CF0	2.8 ± 1.3	3.3 ± 0.6	3.1 ± 0.7	2.9 ± 0.8	3.0 ± 0.5	2.5 ± 0.6
RF0	3.2 ± 1.7	3.3 ± 0.4	3.1 ± 0.4	3.9 ± 1.3	3.6 ± 0.7	3.1 ± 0.9
CF4	2.3 ± 1.3	3.0 ± 0.6	2.7 ± 0.6	2.0 ± 1.0	2.2 ± 0.4	2.0 ± 0.6
RF4	2.8 ± 0.6	3.3 ± 0.7	3.0 ± 0.7	3.4 ± 0.8	3.2 ± 0.7	3.0 ± 0.8
CF8	3.0 ± 0.7	2.4 ± 0.4	2.1 ± 0.4	3.8 ± 1.3	3.5 ± 0.7	3.0 ± 0.8
RF8	2.5 ± 1.1	2.8 ± 0.9	2.4 ± 0.9	3.1 ± 1.0	3.6 ± 0.6	3.2 ± 0.7
CF12	2.9 ± 0.7	3.5 ± 0.4	3.1 ± 0.6	3.8 ± 0.9	4.0 ± 0.7	3.6 ± 0.7
RF12	3.3 ± 1.2	3.3 ± 0.6	2.9 ± 0.8	3.7 ± 1.4	3.7 ± 0.7	3.3 ± 0.9

[1]Log_{10} colony-forming units per milliliter of rinse.

[2]Type of feed and times off feed treatments are described in Table 1.

[3]n = 8 carcasses per mean (4 carcasses/replication); $P > 0.05$.

treatment groups (RF0, RF4, RF8, and RF12) had comparable NYD2 values, but this was not the case for the carcasses within the control treatment groups (CF0, CF4, CF8, and CF12). Moreover, there was no definite pattern for the NYD2 results for the control treatment groups.

Prechill eviscerated carcass weights (shell weight) were not significantly different due to treatment (1.77 to 1.84 kg; Table 5). Similarly, no difference was found in shell weight (shell yield; SH) due to treatment when the values were expressed as a percentage of the catch weight (SH1) or as a percentage of the NY dressed weight (SH3). This was not the case when the shell weight was expressed as a percentage of the dock weight (SH2). For SH2, the highest yields occurred for broilers held without feed for 8 or 12 h, irrespective of the type of feed (71.9 to 72.6%). This result indicates that more of the dock weight for broilers within the CF8, RF8, CF12, and RF12 treatment groups was converted into edible yield (i.e., the intestinal tracts were more empty for these birds just prior to processing).

Table 6 shows the effect of treatment on bacteria recovered from WCR before (NY dressed) and after (shell) evisceration. No difference was observed in counts of *Campylobacter* ($\log_{10}$ 2.3 ± 1.3 to $\log_{10}$ 3.3 ± 1.2), coliforms ($\log_{10}$ 2.4 ± 0.4 to $\log_{10}$ 3.5 ± 0.4), or *E. coli* ($\log_{10}$ 2.1 ± 0.4 to $\log_{10}$ 3.1 ± 0.7) due to treatment for NY dressed carcasses. Similarly, no difference due to treatment was observed for counts of *Campylobacter* ($\log_{10}$ 2.0 ± 1.0 to $\log_{10}$ 3.9 ± 1.3), coliforms ($\log_{10}$ 2.2 ± 0.4 to $\log_{10}$ 4.0 ± 0.7) or *E. coli* ($\log_{10}$ 2.0 ± 0.6 to $\log_{10}$ 3.6 ± 0.7) for shell carcasses. WCR of birds in the CF4 treatment group had 5/8, 6/8, and 6/8 carcasses testing positive for *Campylobacter*, coliforms, and *E. coli*, respectively. These data demonstrate that recovery of bacteria from carcasses of birds fed RF was not significantly different from recovery of bacteria from birds fed traditional starter feed.

Results of the present study indicated that feeding broilers RF for 8 h caused less live shrink as compared to CF (traditional starter) and did not significantly alter carcass bacteria recovered during WCR. Additionally, the 4-h feed withdrawal recommended by the feed manufacturing company for birds fed RF gave higher (1.6% higher) NY dressed yield when expressed as a percentage of dock weight (NYD2) than that observed for broilers fed control feed and subjected to feed withdrawal of 12 h (industry standard).

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